Microgrid Planning and Operations for Critical Facilities Considering Outages due to Natural Disasters*)

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DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
ANALYTICS | PLANNING | OPERATIONS

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BERKELEY LAB
Lawrence Berkeley National Laboratory

DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA

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Objective of work

- ✓ Modification of DER-CAM
  - ✓ To reflect critical loads in microgrids
  - ✓ To easily turn sites with existing DER/CHP into microgrids
  - ✓ To plan and operate microgrids in response to outages due to natural disasters (hurricanes, earthquakes) and cyber attacks
  - ✓ To increase grid resilience
- ✓ Transferability of DER-CAM
  - ✓ For use by multiple clients at multiple sites, e.g. CHP sites in NJ, NY, CA
  - ✓ Tool for Users: user guide, training, analysis and support

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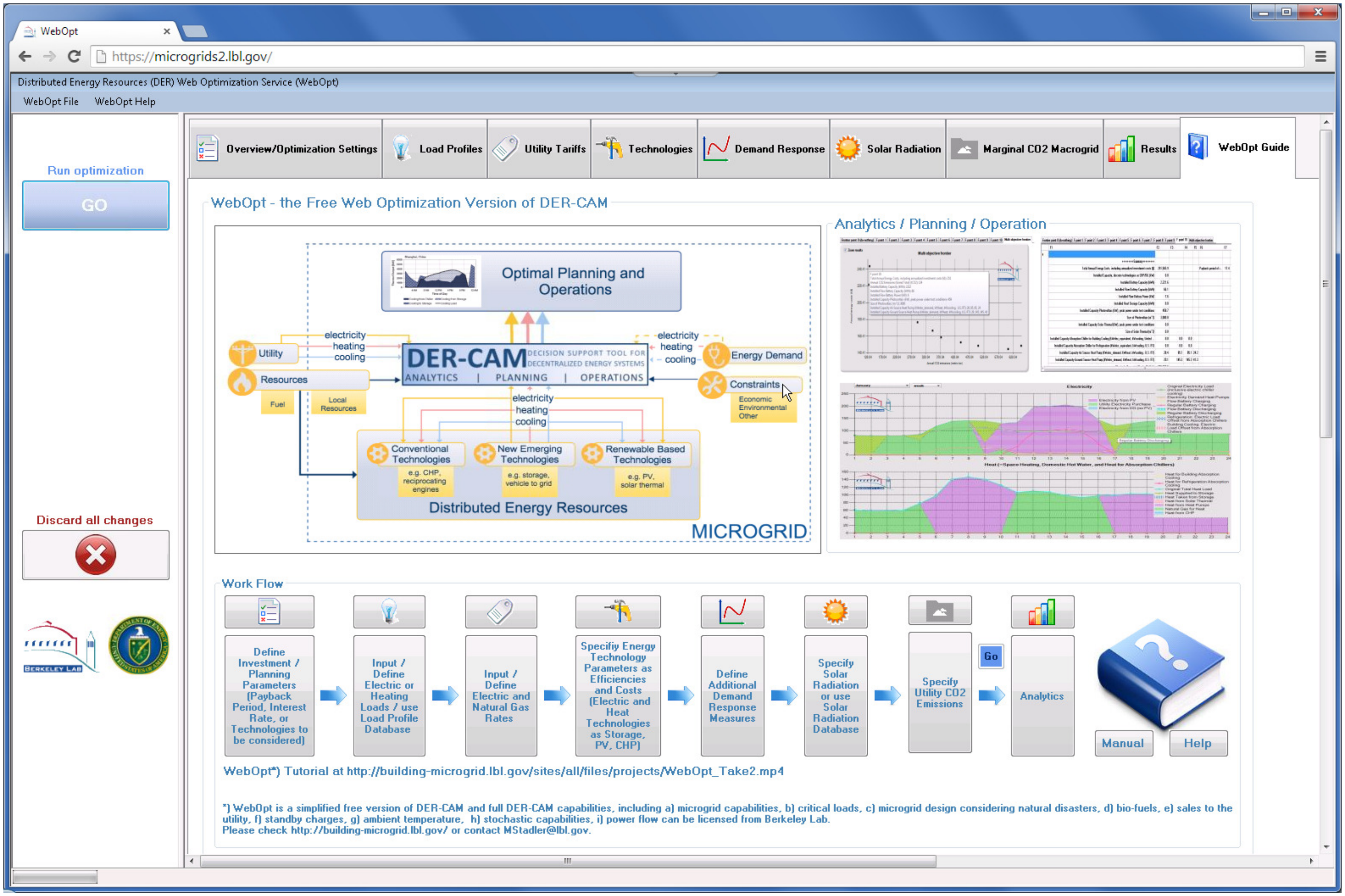
Transferability: Online DER-CAM User guide



http://building-microgrid.lbl.gov/projects/distributed-energy-resources-web

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Transferability: Partners

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MIT Lincoln Laboratory

Department of Defense United States of America

The University of New Mexico

Linköpings Universitet

TU Wien ESEA Institut für Energiesysteme und Elektrische Antriebe

Waseda University 早稲田大学

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New features: microgrid capabilities, designed for resiliency

Applications: Plan microgrids to enhance grid resiliency

- *Enhanced microgrid capabilities*
  - Islanding – intentional and unintentional
  - Load prioritization / critical loads
- *Increased resilience*
  - Optimize islanded dispatch
  - Fully utilize backup generation
  - Determine offline fuel needs (tank sizes)

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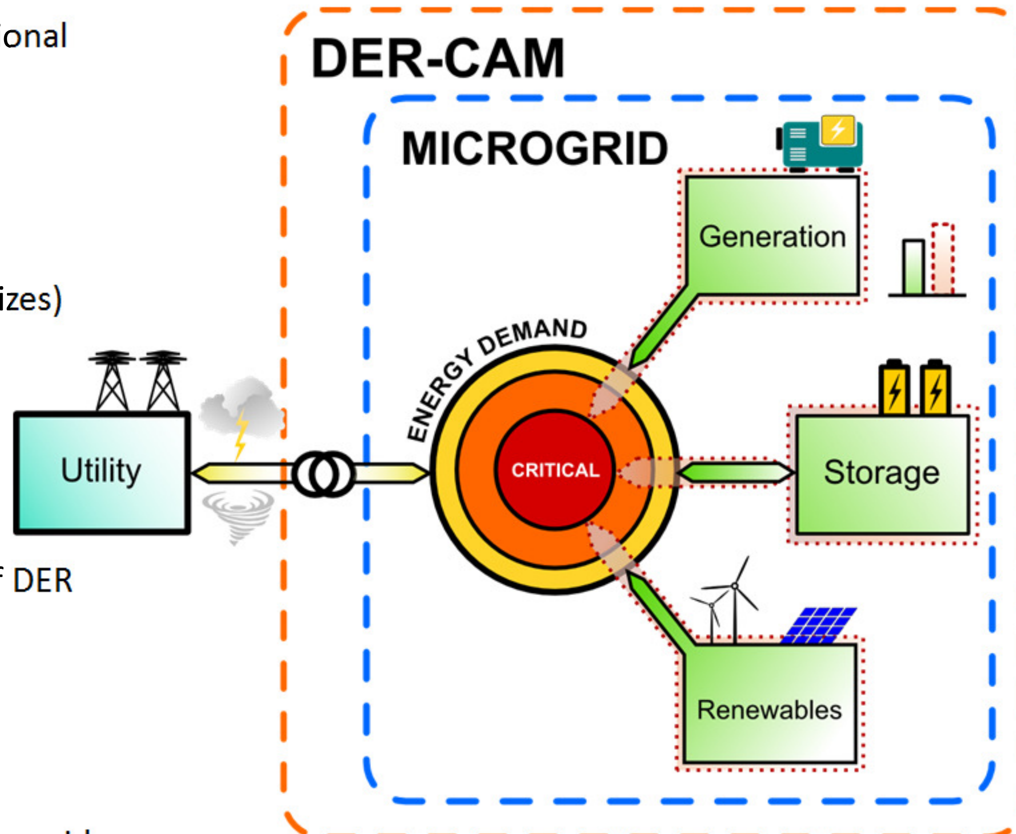
- *Minimize costs and CO_2 emissions*
  - Local heat and power generation
  - Energy storage
  - Optimize grid-connected dispatch of DER
- *Microgrid siting*
  - Optimize dispatch of existing DER
  - Plan new DER capacity
  - Identify microgrid candidate sites
  - Turn sites with existing CHP into microgrids



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New features: microgrid capabilities, designed for resiliency

- *Voluntary & forced islanding*
  - Grid availability from reliability model: MTTF / MTTR
  - Reliability measured by un-served energy
  - Variable outage length (from a few minutes to several days or weeks)
  - Voluntary islanding determined by microgrid economics
- *Load Prioritization / Critical loads*
  - User defined load priorities (up to 3 priority levels)
  - Max. acceptable shedding amount and duration per load priority
  - Economic trade-off for each priority level determines load shedding vs. backup DER
  - Direct load control modelling
- *Optimize offline (islanded) dispatch*
  - Energy management strategies (load shifting / shedding)
  - Energy storage
  - Resource availability – for extended times after outages, e.g. 7+ days
- *Plan Backup generation*
  - Trade-off: additional capacity vs. backup-only
  - Offline fuel needs

changed technology adoption

New microgrid capabilities in DER-CAM provide the first step in the Microgrid Design Toolkit

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Fort Hunter Liggett (FHL) – Test Case

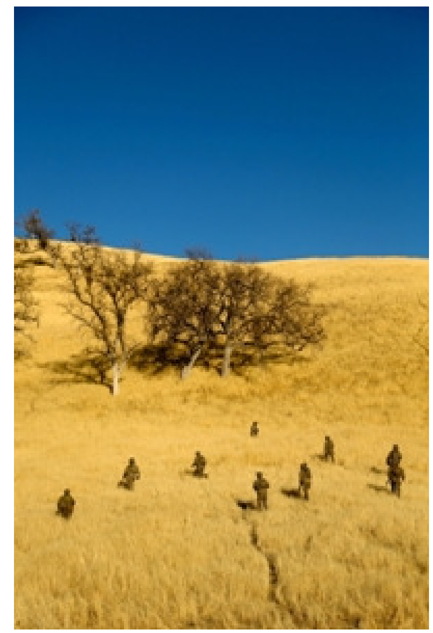
Overview

- Training facility for combat support and combat service support units of the Army Reserve
- Largest installation in the Army Reserve (> 165,000 acres)
- Existing DER: 2MW PV + 1MWh battery
- Future: Large (>1MW) PV and battery system
- together with Siemens and the U.S. Army

Objective: Enable Microgrid capabilities for short and medium-term outages

DER-CAM Contribution

- Use DER-CAM to gauge optimal capacity of DER
    - Consider additional PV and storage
    - Backup generation
    - Short vs. long duration blackouts
    - Optimal DER capacity



source: http://www.liggett.army.mil/

Scalable and transferrable approach: New Jersey, New York, CEC, CPUC, etc.

Can be used today in NJ and NY

Fort Hunter Liggett – DER-CAM Assessment

Objective: Use DER-CAM to perform a quick assessment of optimal DER at FHL to enable microgrid capabilities. Focus on resilience against natural disasters.

- Blackout cases: none, 3 h, 24 h, 7 days

- Standard DER-CAM assessment (no blackouts):
  - Existing DER (BAU)
  - Existing DER + additional PV and storage
  - Existing DER + additional DER (full DER-CAM technology range)

- DER-CAM assessment considering blackouts:
  - Existing DER (BAU)
  - Existing DER + additional PV and storage
  - Existing DER + Diesel backup generators
  - Existing DER + additional PV, batteries and diesel backup generators
  - Existing DER + additional DER (full DER-CAM technology range)

Load prioritizations: 10% Critical loads; 20% Low Priority; 70% Medium priority

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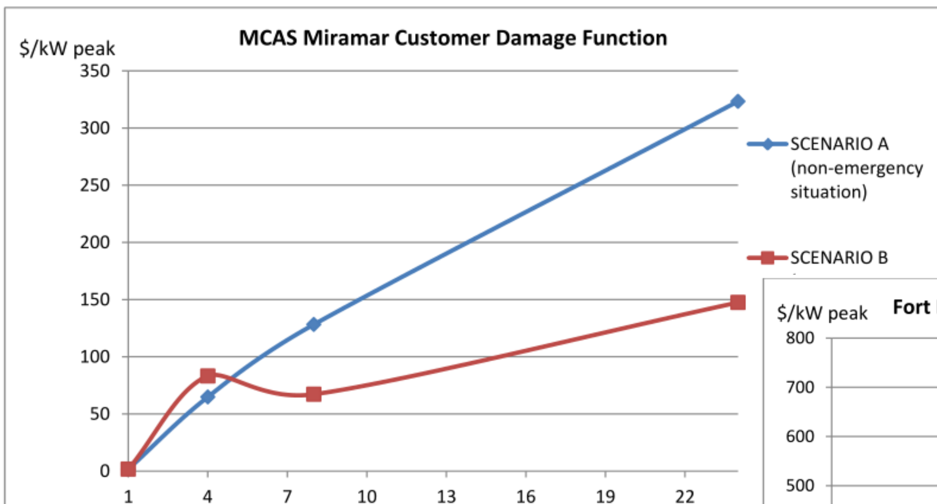
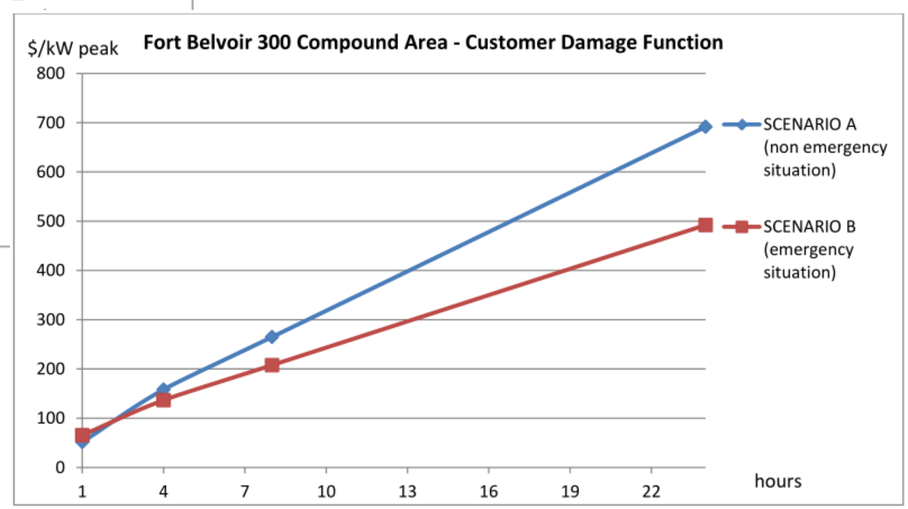
Fort Hunter Liggett – Customer Damage Function (CDF)

Customer Damage Function is used to estimate outage costs as a function of the outage duration.

*Value of Electrical Energy Security (VEES) ~ Outage Duration * $/kW peak * Peak Demand*



Source:
Valuing Energy Security: Customer Damage Function Methodology and Case Studies at DoD Installations, NREL



Fort Hunter Liggett – Standard DER-CAM assessment - no blackouts

Key Results*)

	BAU/Actual	Additional PV + Storage	All possible DER in DER-CAM
Annual Total Costs, million USD	3.035	2.948	2.701
Annual CO_2 emissions, ton	4967	4161	4454
Photovoltaic, kW	2000	3032	2069
Electric Storage, kWh	1000	4141	1251
ICE, kW	-	-	2000
CHP: ICE + HX, kW	-	-	500
Absorption Chiller, kW	-	-	2828
Solar Thermal, kW	-	-	784

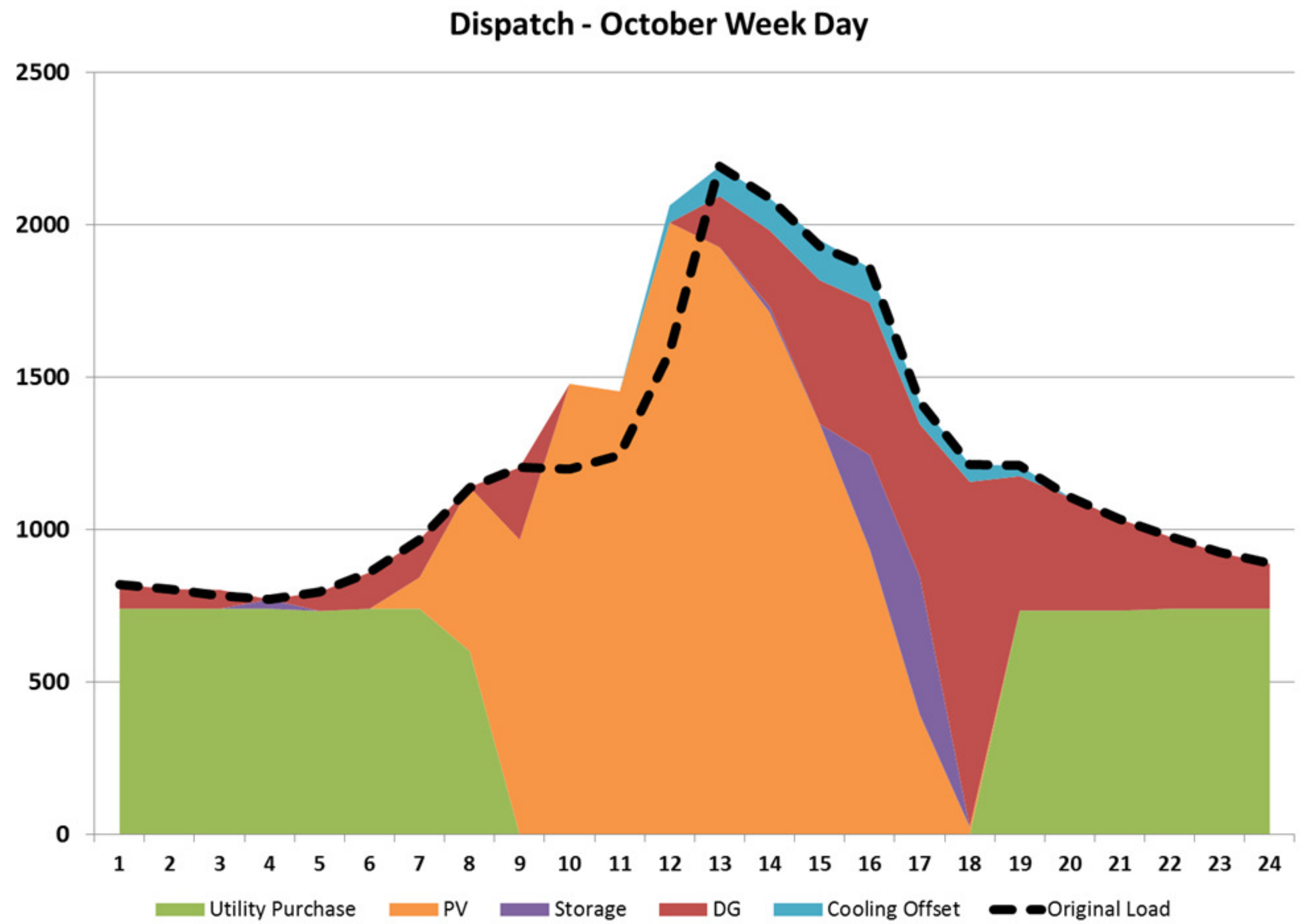
- Allowing additional PV and storage shows that the optimal investment capacity is higher, which is in accordance with the existing expansion plans of FHL
- Allowing other DER shows potential to reduce energy costs by up to 11% and CO_2 reductions by 10%

*) Sales are not part of this analysis

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Fort Hunter Liggett – Standard DER-CAM assessment - no blackouts



All DER technologies allowed

PV generation enables frequent voluntary islanding (no energy purchase during the day)

Fort Hunter Liggett – DER-CAM assessment – with 3h blackout

Key Results*)

(Costs in million USD)	Existing PV and Storage	Existing PV, Storage + Diesel Backup	Additional PV and Storage	Additional PV, Storage and Diesel Backup	All DER
TOTAL COSTS	3.050	3.043	2.948	2.948	2.701
Electricity Costs	2.218	2.218	1.703	1.692	1.147
Fuel Costs	0.320	0.320	0.320	0.320	0.475
Annualized Capital Costs	0.491	0.493	0.915	0.926	0.974
O&M Costs	0.001	0.001	0.001	0.001	0.035
CDF Costs	0.015	0.005	-	-	-
Annual CO_2, ton	4966	4967	4177	4161	4455
Installed capacity					
Photovoltaic, kW	2000	2000	3079	3032	2068
Electric Storage, kWh	1000	1000	3845	4141	1251
Diesel Backup, kW	-	200	-	-	-
ICE, kW	-	-	-	-	2000
ICE HX, kW	-	-	-	-	500
Absorption Chiller, kW	-	-	-	-	2828
Solar Thermal, kW	-	-	-	-	783

- 3h blackout has little to no effect on results
- Existing capacity can be dispatched to meet all electric loads during short duration blackouts (some backup generators already exist at FHL)

*) Sales are not part of this analysis

Fort Hunter Liggett – DER-CAM assessment - 24h blackout

Key Results*)

(Costs in million USD)	Existing PV and Storage	Existing PV, Storage + Diesel Backup	Additional PV and Storage	Additional PV, Storage and Diesel Backup	All DER
TOTAL COSTS	5.363	3.068	3.655	2.976	2.702
Electricity Costs	2.216	2.216	0.785	1.661	1.145
Fuel Costs	0.320	0.326	0.320	0.324	0.477
Annualized Capital Costs	0.491	0.510	2.475	0.971	0.976
O&M Costs	0.001	0.001	0.001	0.001	0.036
CDF Costs	2.330	0.009	0.059	0.010	0.000
Annual CO_2, ton	4955	4973	2132	4119	4444
Installed Capacity					
Photovoltaic, kW	2000	2000	4936	3106	2077
Electric Storage, kWh	1000	1000	20709	4374	1250
Diesel Backup, kW	-	1400	-	1000	-
ICE, kW	-	-	-	-	2000
ICE HX, kW	-	-	-	-	500
Absorption Chiller, kW	-	-	-	-	2807
Solar Thermal, kW	-	-	-	-	801

- Results show that additional PV and storage, in addition to backup generation, will allow FHL to survive 24h outages without any major service disruption at low costs – diesel consumption roughly 1250 gallon for 24h
- When considering all DER options, the optimal investment solution allows enough flexibility to maintain operation during 24h outages and lowest costs

*) Sales are not part of this analysis

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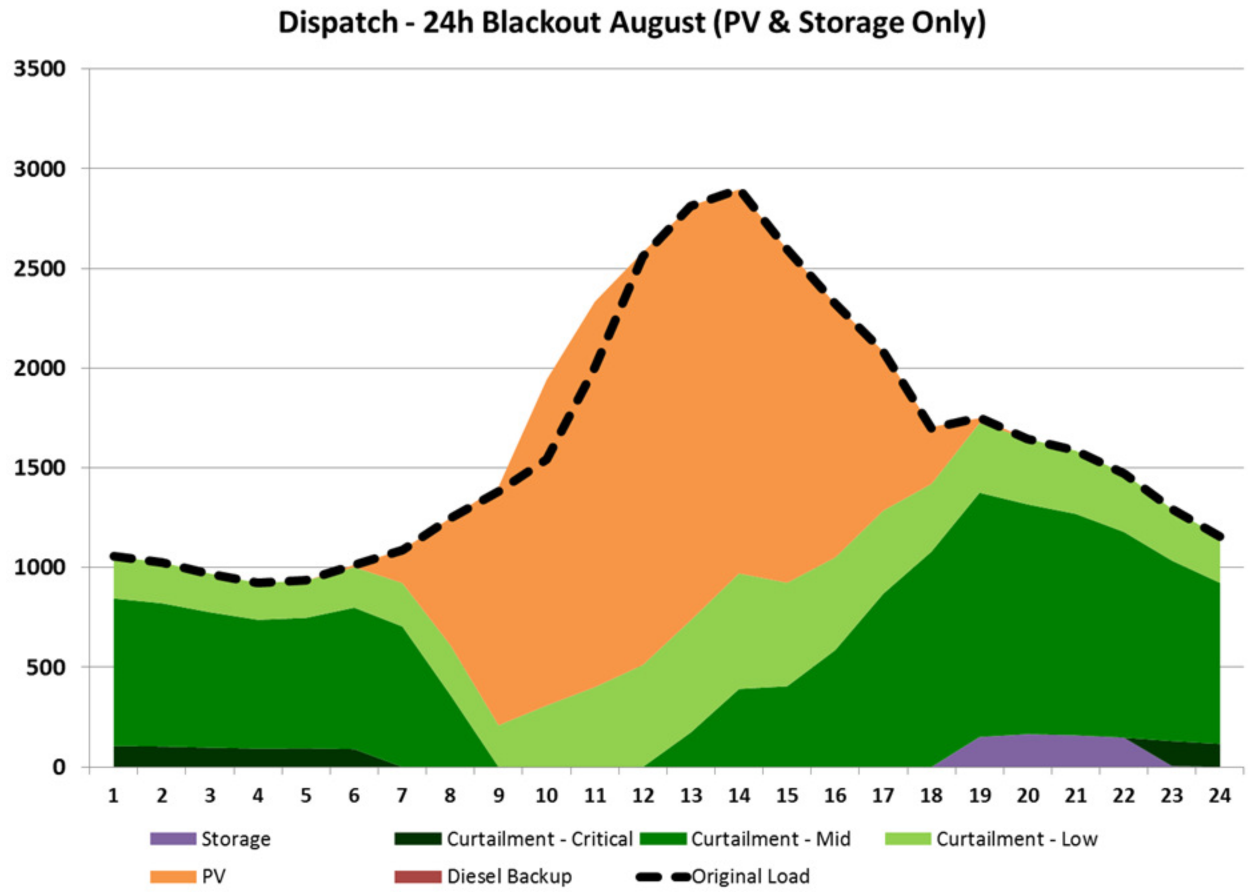
Fort Hunter Liggett – 24h blackout



With the current PV and storage capacity alone, FHL would have severe curtailments in the event of a 24h outage, and would not be able to supply all critical loads

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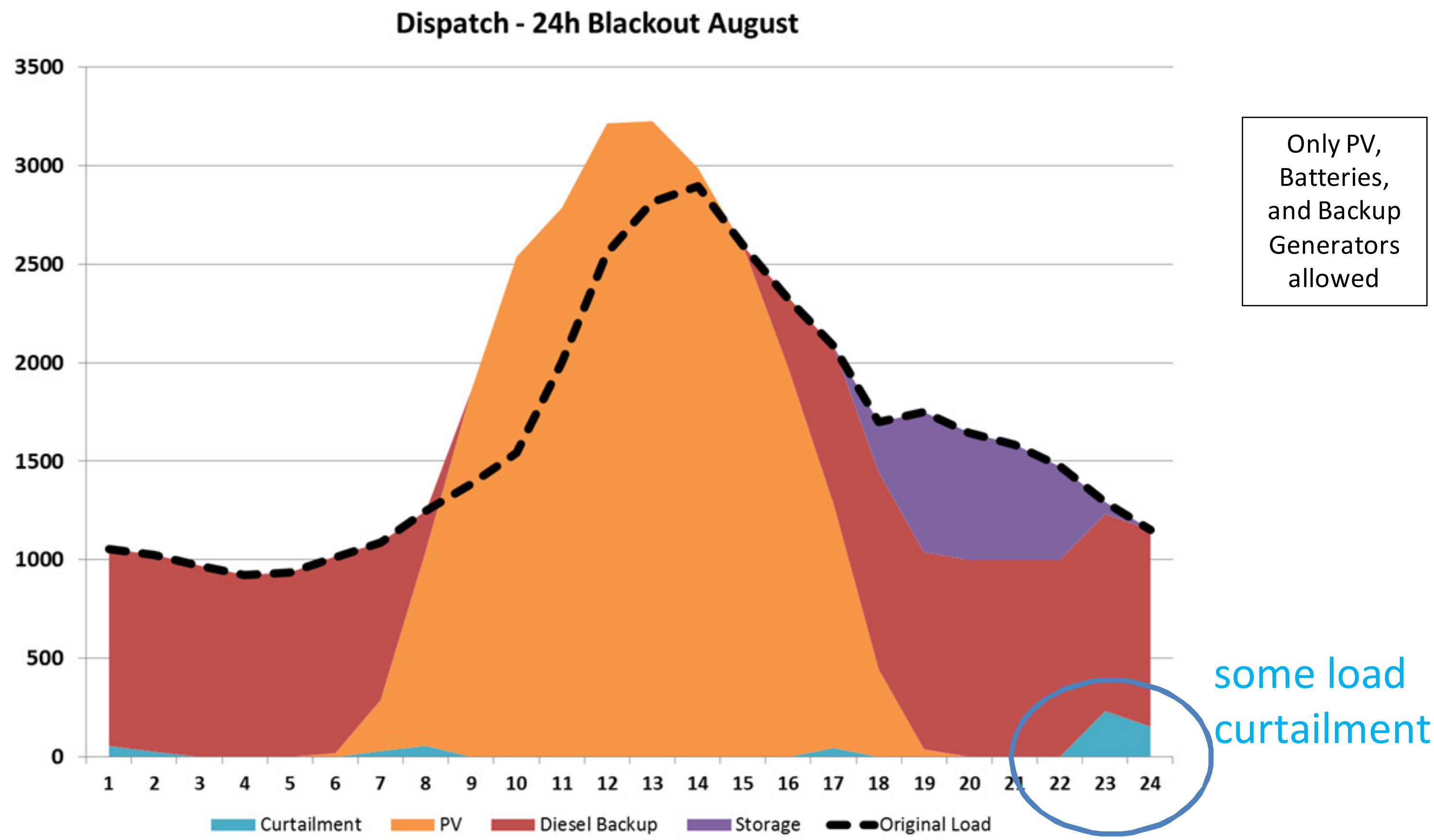
Fort Hunter Liggett – <u>24h blackout</u>



Planned expansion of PV and Storage, together with Diesel backup generators will allow increased resilience at FHL

Fort Hunter Liggett – 7 day blackout

- Extremely high costs in prolonged outages with current resources (with existing equipment 24 million USD, all DER allowed only 3 million USD)
- Additional backup capacity increases significantly (up to 8 MW)
- Considering the capacity of DER to be implemented at FHL, the ability to maintain operation during prolonged blackout periods relies only on the size of fuel storage (fuel storage sizing) – consumption during blackouts approx. 3300 gallon LNG for 7 days

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Fort Hunter Liggett – Main conclusions of DER-CAM assessment

- The microgrid-enhanced DER-CAM capabilities are readily available and easy to use for assessing the optimal capacities in microgrids, with/without consideration of blackouts – both short and long duration
- Using the microgrid & resilience features implemented in DER-CAM it is possible to get timely information on costs resulting from blackouts
- These features allow evaluating the readiness of candidate microgrid sites by estimating the costs of incremental investments required to build and operate in islanded mode
- The approach described in the FHL example is flexible, scalable and easily transferrable, making DER-CAM a highly valuable tool for first order DER assessments in microgrids (first step in the ***Microgrid Development Toolkit - MDT***)
- currently: trained DER-CAM person can achieve these results in less than 2 days of work
- <u>Next steps</u>:
    - Transfer to beta sites in NJ, NY and CA
    - Implement new features in web interface (goal: allow assessments in a couple of hours for every user)
    - Add simplified power flow (topology: location choice of technologies)